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APPLICATION OF ACOUSTIC SOUNDING SYSTEM FOR ENVIRONMENTAL STUDY

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ध्वनिक अनुनादी सिस्टम में निचले वायुमण्डल की वायु एवं अशान्त ऊष्मीय संरचना की पारस्परिक क्रिया का उपयोग किया जाता है। पश्च-प्रकीर्ण करने वाले **मोनोस्टेटिक सोडार** (mono-static sodar) से प्राप्त प्रतिध्वनिप्रलेख की अनुलिपि को देखकर अशान्त क्षेत्रों की उपयोगी गुणात्मक जानकारी एवं अनुनाद स्थल के ऊपर उनकी ऊँचाई का पता लगाया जा सकता है, जबकि डॉपलर सोडार (Doppler sodar) से प्राप्त संकेत की आवर्तिता के आयाम और 'डॉपलर परिवर्तन' से प्रकीर्णित आयतन के संरचना प्राचलों, अशांति और वायु क्षेत्र की मात्रात्मक जानकारी प्राप्त की जा सकती है। अशांत प्राचलों यथा ताप और गति में उतार-चढ़ाव की संरचना, ऊर्ध्वाधर वेग विसंगति, क्षैतिज वायु वेग में परिवर्तन, वायु दबाव, समीचीन ताप का प्रवाह, वेग घर्षण, ऊर्जा के छितराव की दर, स्थिरता के विभेद, मिश्रण क्षेत्र की ऊँचाई आदि के मापन के लिए ध्वनिक अनुनादकों का प्रयोग एक यंत्र की तरह किया जाता है। इन प्राचलों का उपयोग घटना-क्रिया-विज्ञान के माडेलों के प्रमाणीकरण के लिए किया जाता है। वायु-गुणवत्ता के आकलन तथा वायु प्रदूषण के नियंत्रण में इनका बहुत महत्व है।

आलेख में ध्वनिक अनुनादी सिस्टम के सिद्धांतों पर प्रकाश डालते हुए पर्यावरण प्रबोधन में इसके महत्व और वायुमण्डलीय सीमा परत से संबंधित अध्ययनों में इसकी उपयोगिता को दर्शाया गया है।

INTRODUCTION

It is commonly known that the serious air pollution episodes have not generally been caused by the sudden increase in the emission of pollutants but have rather been caused by the drastic decrease in the ability of the atmosphere to disperse the pollutants. The ability of the atmosphere to accumulate or disperse the pollutants is an important parameter, which needs to be monitored on a continuous basis. Acoustic sounding has proved to be an efficient and valuable remote sensing tool for investigating the dynamics of the lower atmosphere. This technique provides excellent means of monitoring the lower boundary layer of the atmosphere because acoustic waves interact strongly with thermal structures of the atmosphere (McAllister, 1968). It is due to this strong interaction that today acoustic sounding is an important component in almost all atmospheric monitoring programmes. The acoustic sounder presents record of the Atmospheric Boundary Layer (ABL) in a simplified manner (Singal and Gera, 1982; Garrat, 1992).

The recently developed ground based remote-sensing technique sodar (Sound Detection And Ranging) can probe the atmosphere up to a height of 1-2 km. Apart from being useful in air pollution applications, sodar is also very powerful in carrying basic atmospheric studies, such as boundary layer modelling and surface atmosphere interaction (Best et al., 1986; Gera and Singal, 1990; Melas, 1990; Venkatesan et al. 1995; Singal. 1997; Chaulya et al., 2001). Sodar provides basic data on meteorological parameters, relevant to atmospheric dispersion at a desired height and time interval (Gera and Singal, 1990). Dispersion is an important tool to study air pollution. The mode of measurement of sodar is different from conventional tower or balloon mounted setups. Conventional setup gives measurement at a single point in the atmosphere, whereas sodar data gives average over a volume in the space. Sodar is a ground based remote sensing technique and so it is not intruded into the space at the point of measurement. It provides better temporal and spatial coverage with higher resolution in profiling winds at selected levels and hence can locate layered structure in the atmosphere (Sen Gupta et al., 1986; Venkatesan et al., 1995). Sodar can provide on site, on-line data of all the parameters such as temporal and spatial variation of wind speed, wind direction, stability or turbulence intensity along with Thermal structure (Bandyopadhay et al., 2001).

Atmospheric dispersion is mainly governed by mean wind speed, wind direction, fluctuations in wind speed characterizing atmospheric turbulence and vertical temperature profile or thermal structure (Peavy et al., 1985; Best, 1986). Mean wind speed and direction govern the pollutant plume movement in down wind sector. With the wind speed of 1-5 m/s, the effluents can travel to distances of a few tens of kilometers in few hours. The turbulence intensity or atmospheric stability governs the diffusion spread of the effluents in the crosswind and vertical directions (Hanna et al., 1982). At lower heights the turbulence intensity or atmospheric stability shows a wide variation (McAllister, 1968). Thermal structure in terms of thermal turbulence (or thermal activity) in the

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atmosphere is an indirect index of the temperature profile in the vertical direction, which determines the presence or absence of layered structure in the atmosphere (Singal, 1982; Melas, 1990; Abbate et al., 1994). The presence of such layers has an important bearing on the dispersion (Peter and Coils, 1981).

With a view to study the parameters of ABL and subsequently for air quality modelling over a dominantly mining area, a mono-static sodar and a Doppler sodar were installed at Central Mining Research Institute, Dhanbad. This paper describes a comprehensive description of both types of sodas, their application and interpretation of data including representation of observed data of Dhanbad region.

SIGNIFICANCE OF MICRO-METEOROLOGICAL PARAMATERS

Micro-meteorological properties of the atmosphere, govern the concentration of pollutants and its variation with time and location, with respect to the sources (Hanna et al., 1982). The severity of pollution depends on the following meteorological variables (Turner, 1970; Dhar, 1996; Chaulya, 1998):

- Wind speed and direction;
- Atmospheric diffusion (Stability class);
- Temperature variation with height, including lapse rate arid inversion (inversion frequency and mixing height);
- Precipitation; etc.

The following non-meteorological factors also affect air pollution

- Topographical features; and
- Quality and quantity of pollution.

The lowest portion of the earth's atmosphere is known as the Troposphere. It extends from the ground to a height of about 15 km, with the upper limit varying with geographical location of the place. One of the significant features of the troposphere is that the temperature in the atmosphere is not constant but varies with height, season, time of day, amount of cloud cover and other variables. The temperature decreases with height, which is maintained right up to the tropopause. At average rate of vertical temperature decrease is 6.5°C / km. The decrease of temperature with increase in vertical height is called "Lapse rate" and is controlled by dynamic processes in the Troposphere (Riehl, 1972).

The ability to describe general atmospheric dispersion conditions demonstrates a fundamental understanding of atmospheric transport; more importantly, limiting times, months, or seasons can be identified during this process, and this information can be used in construction-phase planning and operational-phase decision-making. Data indicative of the general characteristics of the area with regard to air pollution dispersion include mixing height, inversion height and mean annual wind speeds. "Mixing height" refers to the vertical distance available above the earth's surface at a given location and at a given time (or during a given period) for the mixing of pollutants. The mixing heights vary daily, seasonally and topographically (Bandyopadhyay et al., 1997). This parameter is essential in estimating the amount of vertical diffusion of pollution in the atmosphere (Peavy et al., 1985; Prasad et al., 1997).

Change of the temperature lapse rate, i.e., from negative to positive, resulting in stable atmospheric condition is known as "inversion". Temperature inversion may be said to be a meteorological condition in which air pollutants are unable to rise and disburse in the atmosphere, thereby causing high concentration of pollution (Lehr et al., 1957; Pettersen, 1968). Inversion occurs frequently, during the night or early morning hours. Inversion temperatures are usually limited up to the first 500 m and this is therefore, the normal inversion height (Battan, 1979). "Inversions" occur when temperature increases with height above the earth's surface (Weill et al., 1978). Inversions typically are present during the night or early morning hours because of the heating and cooling pattern at the earth's surface. In general, inversions are more frequent during the fall than during any other season. One of the characteristics of inversion is that they are often accompanied by wind speeds less than 11 km/h; thus, they often represent time periods when there is limited horizontal and vertical dispersion.

The two basic factors that influence the movement of pollutants from their points of origin to some other location are "horizontal wind speed and direction" and the "vertical temperature structure" of the atmosphere. These two parameters influence the vertical and horizontal motion of pollutants released to the atmosphere (Davis, 1973). The influence of these two parameters can be combined and the joint parameter is then called "atmospheric stability'. Atmospheric stability is divided into six classes, namely A, B, C, D, E and F classes, Class A indicates the greatest amount of spreading under the most unstable atmospheric conditions, whereas class F indicates the least amount of spreading under the most stable atmospheric conditions (Kumar and Choudhury, 1991; Prasad et al., 1996).

Finally, "mean annual wind speeds" can be used as general indicators of dispersion conditions. Larger numerical values are more desirable because they signify the more rapid dispersion of air pollution from a given area.

TYPES OF SODAR

There are two types of commonly used sodar, namely mono-static and Doppler. A distinction is made by Singal (1989) between mono-static and Doppler sodar equipment.

The mono-static sodar measures the sound scattered back to the transceiver (scattering angle 180°) Usually a single antenna is used to both transmit and receive. A combined transmitter/receiver (transceiver) is used which switches alternately between transmit and receive modes. The transducers in the antenna work alternately as loudspeaker and microphone. A single antenna receives signals scattered back from a wide range of heights. Mono-static sodar gives only qualitative representation of ABL up to 1 km height from the surface. It is used to study the structure of the lower atmosphere. Acoustic facsimile charts, depending on the applied gain and dynamic range of the system, indicates the presence of ground based activity of thermal plumes, nocturnal inversions, and turbulent thermal structures of the lower atmosphere associated with fog, thunderstorm and land and sea interaction, and mesoscale atmospheric phenomena (Singal, 1989).

In Doppler sodar equipment, numbers of elements in a phased array antenna system are used to transmit and receive signals. Its friction is based on Doppler shift measurement technique. Doppler sodar gives both qualitative and quantitative data of ABL up to 2 km height from the surface. It is used to give a measure of turbulence parameters like structure parameters of temperature and velocity fluctuations, vertical velocity variance, variations in horizontal wind velocity, wind shear, sensible heat flux, friction velocity, energy dissipation rates, stability classification, mixing height and entrainment coefficients (Singal. 1989).

PRINCIPLE OF SODAR

Mono-static Sodar

Sodar, a Sound Radar, is a remote sensing equipment, usually used to monitor atmospheric wind and thermal fluctuations by measuring back-scattered echoes generated from an acoustic tone burst. The backscatter is large from inhomogeneities whose size is around half the wavelength of the sound used (Bragg resonance). The time taken for the sound to travel to the inhomogeneity and return to the receiver is a measure of the distance between the receiver and the scattering inhomogeneity (target). Continuously operated, sodar generates enormous data, which have to be processed for prediction of atmospheric behaviour. The parameters are determined through the echograms (Singal et al., 1984; Singal et al., 1986). The mixing height is determined by interpretation of the echograms (Beyrich, 1995).

Doppler Sodar

In the sodar method, pulses of audible sound are radiated and focused vertically upward in time packets into the atmosphere. A fraction of the sound energy is scattered back from inhomogeneities of the acoustic refractive index of the atmosphere and is received back at the antenna. If the scattering inhomogeneity (target) is moving, then the back-scattered signal is shifted in frequency from transmitted frequency (Doppler effect, which is elaborated below). The time taken for the sound to travel to the inhomogeneity and to return the receiver is a measure of the distance between the sound source/receiver and scattering homogeneity. From the transmit time, intensity and frequency shift of the returned signal; it is possible to calculate the profiles of the back scattered amplitudes in the beam direction and their standard deviations. From the calculated values of horizontal and vertical wind speeds, their standard deviations, wind direction and its standard deviation, it would further be possible to have information about mixing height and stability class over the region (Beyrich, 1997).

Doppler effect: If a sound source transmits at a frequency f_o then an observer moving at a velocity r towards or away from the source observes a frequency shift of

$$f_1 = f_o \cdot (1 \pm r/c)$$

Where c is the speed of sound. If the observer is moving towards the source, the shift in frequency is positive (higher frequency, +), while if he is moving away, the shift is negative (lower frequency, -). The same applies if the observer is stationary and the source is moving.

$$f_2 = f_1 \cdot (1 \mp r/c)$$

In SODAR, the target i.e. the inhomogeneities that are causing the scattering, is both "observer" and "source. The frequency shift is thus:

$$f_2 = f_o \cdot (1 \pm r/c) \cdot (1 \mp r/c)$$

or

$$\Delta f = \pm 2\, f_o \cdot \{(r/c)/(1 \mp r/c)\}$$

Where r is the velocity component of the inhomogeneity or wind parallel to the beam direction, which is determined by the transmitting/receiving sodar antenna. At f_o = 1600 Hz the frequency shift is about 10 Hz for a wind speed of 1 m/s parallel to the beam.

A complete description for the analysis of the Doppler shift is given in George and Clifford (1972).

SYSTEM DESCRIPTION

Mono-static Sodar

Central Mining Research institute, Dhanbad installed a mono-static acoustic sounding system at the roof top of the institute building. The system was developed by CMRI with the help of National Physical Laboratory, New Delhi.

The system basically comprises of a computer PC-AT 486 with colour VGA monitor and printer, a transceiver unit containing band pass filters, a power amplifier, a highly sensitive pre-amplifier, a parabolic dish antenna, and a transducer with horn feed.

The block diagram, shown in Fig. 1, explains the unit-wise functions of the system. A pulsed narrow beam of ground wave of frequency nearly 2000 Hz is transmitted vertically into the atmosphere where it encounters atmospheric inhomogeneities and suffers partial reflection. Same transducer receives the back-scattered waves of very low power. The preamplifier amplifies the received signal, which after filtering is fed to the computer

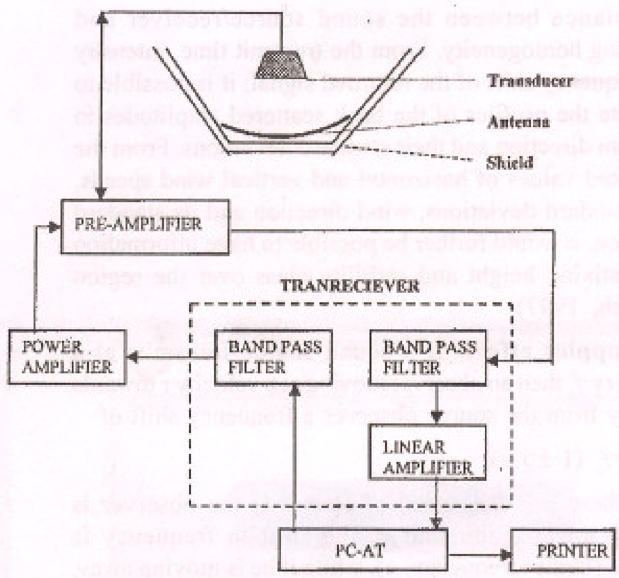

Fig. 1 : Schematic diagram of mono-static sodar

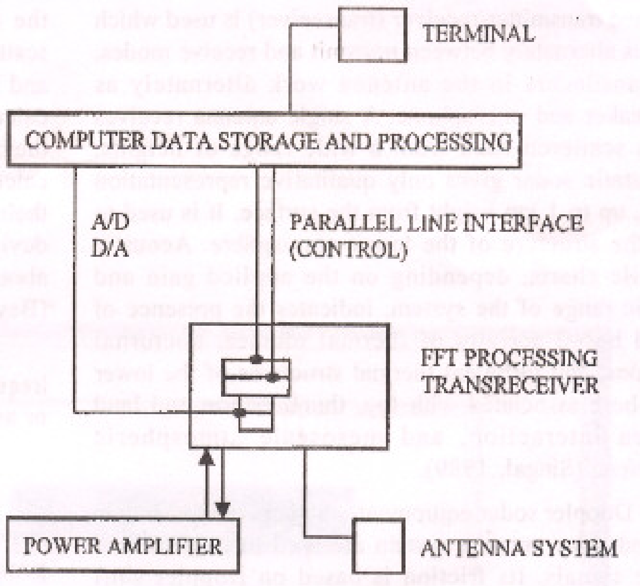

Fig. 2 : Schematic block diagram of Doppler sodar

equipped with ADDA (analog-to-digital and digital-to-analog) card. Computer with highly sophisticated software processes the received signal and the colour monitor displays the atmospheric profile up to 1000 m based on the intensity of the back-scattered wave. The present system, the recording mechanism is most versatile and powerful as it consists various options to record and store the enormous amount of data.

Specification of shield and antenna: A parabolic antenna of 1.8 m diameter and 45 cm height has been employed. The antenna is housed inside a metallic shield unit of 2.4 m height and hexagonal in shape. The inner side of the shield is filled with foam of 10 cm thickness to reduce outside disturbance.

Doppler Sodar

A Doppler sodar imported from M/s Remtech, France was installed in June 1995 at CMRI, Dhanbad. Dhanbad being the nerve center of mining activities, the installation of the Doppler sodar in this region has become very useful to study the environmental parameters and to assess the impact of mining and allied industries over this region.

The Doppler sodar, installed at CMRI, consists of effective and powerful software and hardware devices. The hardware part consists of a 432 elements phased array antenna, transceiver unit, 486 computer with colour monitor and colour printer. The schematic diagram of Doppler sodar System is shown in Fig. 2.

The system electronically generates three beams and calculates the three directional wind speed components by a simple mathematical coordinate transformations and using Fast Fourier Transform Technique (Remtech, 1994). The main characteristic parameters of the installed Doppler sodar are given in Table 1.

Table 1 : Specifications of the Doppler sodar

S.N.	Parameters	Specifications
1	Horizontal wind speed range	0 - 30 m/s
2	Horizontal speed accuracy	0.2 m/s or better
3	Vertical speed range	± 4 m/s
4	Vertical speed accuracy	5 cm/s or better
5	Horizontal direction accuracy	3 degree
6	Receiver gain	100 dB
7	Nominal central operating frequency	2100 Hz
8	Number of elements in antenna array	432
9	Acoustic power	80 W
10	Maximum detection range	2000 m
11	Minimum altitude	35 m

The software package is very sophisticated and user friendly. The system runs under pre-emptive multitasking operating system allowing different tasks to be executed simultaneously. The main task is, of course, the sodar measuring task. The second task is incharge of all communications with the users. It handles the video terminal, the printer and the COM1 and COM2 serial ports. The third task is the colour display package in graphical modes. The graphical mode of representation of data is very informative, and it can be stored as well as printed out for further analysis. The system has been provided with the three graphic modes namely, vectorial, facsimile and series. The vectorial display is useful for a precise analysis while the facsimile and series options give a global overview of the data and obtain a preliminary understanding of the meteorological situations (Peter and Colls, 1981; Gera and Singal, 1990).

INTERPRETATION OF DATA

Mono-static sodar

The acoustic sounding system provides a visual display of countless atmospheric processes right from ground up to an altitude of 1 km. Acoustic sounder records reveal many usual features of the ABL like stability classification, weather conditions, mixing height etc (Chaudhuri et al., 1992).

Pasquill stability classification: Different type of signatures traced on sodar records under varying atmospheric condition has been used to give information about Pasquill stability classification of the atmosphere (Pasquill, 1974). Pasquill has defined six categories of stability from A to F which can be classified on the basis of data of various meteorological parameters like surface wind speed, wind direction, day-time isolation, night-time conditions, temperature lapse rate, etc (Prasad et al., 1996), Out of various schemes to classify Pasquill stability, mono-static sodar use the scheme of wind direction fluctuation to characterize the various types of sodar structures for recognition of Pasquill stability class (Gera, 1989; Swami, 1996).

Based on the detailed analysis (Singal et al., 1985; Thomas 1986; Singal, 1989), a recognition technique has been worked out for stability classification as indicated in Table 2. Each of the stability class is represented by sodar echogram (Fig. 3) measured at CMRI, Dhanbad on 14th December 1995.

Weather conditions: Sodar echograms have been broadly classified as thermal echos (stalagmite-like structures raising from the ground) and shear echos (horizontal layer echo regions impervious to vertical transport). These echograms of thermal structures can be linked in one form or another to all observed prevailing meteorological conditions in the atmosphere (Singal, 1989; Gera and Singal, 1990).

In the morning, solar heating erodes the surface-based stable layer forming thermal plumes rising torn the ground with the stable layer rising above them (Fig. 4a).

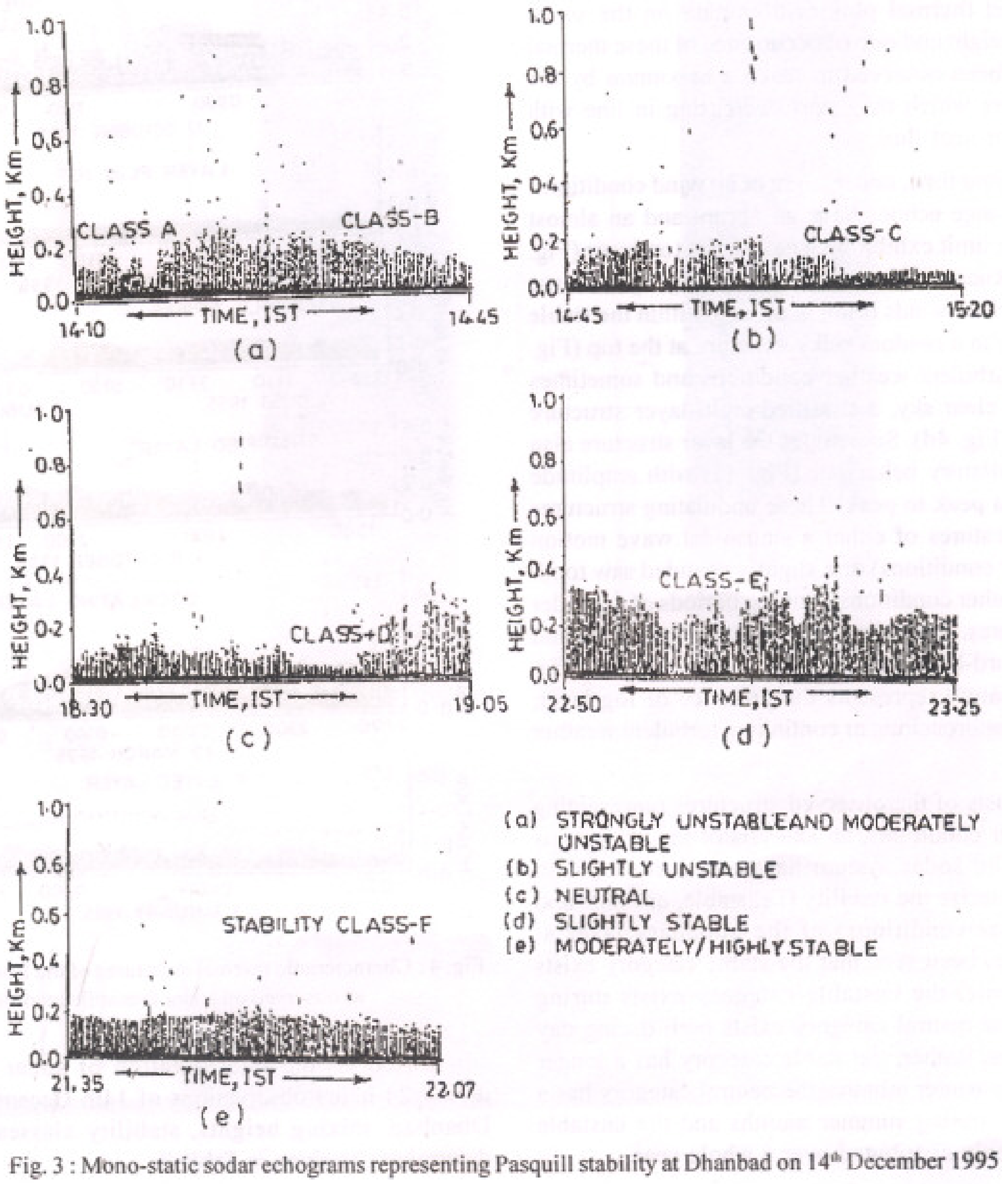

Fig. 3 : Mono-static sodar echograms representing Pasquill stability at Dhanbad on 14th December 1995

Table 2 : Stability classification bastcl on nstore ofsodar ecliogrums

S. N.	Stability class (Pasquill)	Nature of sodar echograms
1	Strongly unstable (A)	Well defined families of tall thermal plumes (Fig. 3 a)
2	Moderately unstable (B)	Well defined thermal plumes up to shallow heights (Fig. 3a)
3	Slightly unstable (C)	Thermal plumes of very shallow heights (Fig. 3b) formed during late afternoon
4	Neutral (D)	Spiky top layers of shallow height (Fig. 3c) either by a structure or by dark hands due to wind induced noise
5	Slightly stable (E)	Ground based layer of higher depth or by a tall spiky structure during night-time or by a stratified layer structure of higher depth (Fig. 3d)
6	Moderately/Highly stable (F)	A shallow and firm ground based layer or by a shallow stratified layer structure (Fig. 3e)

With continued solar heating, the stable layer rises sufficiently (to go beyond the detection range or change turbulence scale, sizes become insensitive to sodar detection) and thermal plumes dominate on the sodar echograms. Height and rate of occurrence of these thermal plumes have been observed to reach a maximum by the afternoon, after which they start decreasing in line with the fall in solar heat flux.

During night time, under slight or no wind conditions, strong short-range echoes have an abrupt and an almost uniform upper limit exhibiting a nearly flat top layer (Fig. 4b). The thickness of these layers may slightly increase with time. Surface winds bring in mixing within the stable layer resulting in a random spiky structure at the top (Fig. 4c). During turbulent weather conditions and sometimes even under a clear sky, a stratified/multi-layer structure may develop (Fig. 4d). Sometimes the layer structure also shows an oscillatory behaviour (Fig. 4e) with amplitude around 100 m peak to peak. These undulating structures may exhibit features of either a sinusoidal wave motion (clear weather conditions) or a slightly rounded saw tooth (turbulent weather conditions), having periods of the order of a few minutes. Sometimes an elevated layer over and above the gourd-based structure may also he seen (Fig. 4f). Such a feature represents the presence of fog layer, subsidence or approaching or continuing turbulent weather conditions.

On the basis of the observed structures representing typical weather conditions, an analysis of the echograms recorded by the sodar system has been carded out to broadly characterize the stability (i.e. stable, unstable and neutral weather conditions) of the boundary layer at Dhanbad. It has been seen that the stable category exists during nighttime, the unstable category exists during daytime and the neutral category exists both during day and night times. Rather, the stable category has a longer duration during winter months, the neutral category has a lesser duration during summer months and the unstable category is evenly distributed over a whole year.

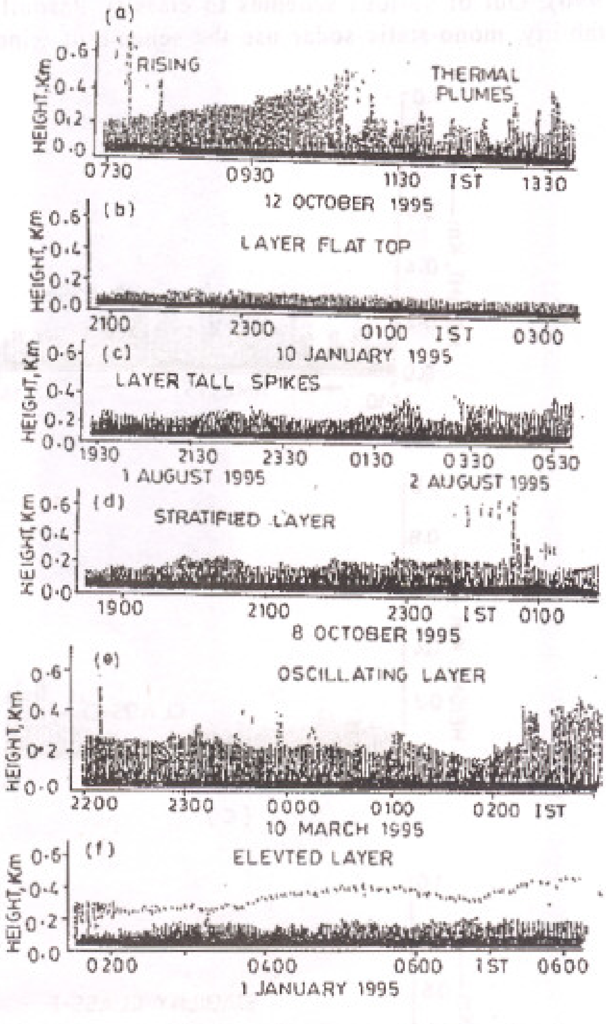

Fig. 4 : Characteristic thermal structures of the Boundary Layer as observed on sodar facsimile records

Based on the interpretation of sodar echograms during 24 hours observations of 14th December 1995 at Dhanbad, mixing heights, stability classes, etc. were determined as given in Table 3.

Table 3 : Interpretation of sodar data

Time	Inversion/ Convection	Plume Height	Ground based		Mixing Thickness	Stability class
			Height	Height		
(IST)	(I/C)	(m)	(m)	(m)	(m)	(Pasquill)
1.00	I	-	246	246	246	E (5)
2.00	I	-	246	246	246	E (5)
3.00	I	-	192	192	192	E (5)
4.00	I	-	154	154	154	E (5)
5.00	I	-	115	115	115	E (5)
6.00	I	-	161	161	161	E (5)
7.00	I	-	161	161	161	E (5)
8.00	I	-	154	154	154	E (5)
9.00	I	-	123	123	123	E (5)
10.00	I	-	108	108	108	E (5)
11.00	I	-	92	92	92	E (5)
12.00	C	-	146	146	146	E (5)
13.00	C	231	-	-	231	B (2)
14.00	C	292	-	-	292	A (10
15.00	C	223	-	-	223	B (2)
16.00	C	238	-	-	238	B (2)
17.00	C	223	-	-	223	B (2)
18.00	C	223	-	-	223	B (2)
19.00	C	223	-	-	223	B (2)
20.00	C	208	-	-	208	C (3)
21.00	C	254	-	-	254	D (4)
22.00	I	-	231	231	231	F (6)
23.00	I	-	231	231	231	B (6)
24.00	I	-	231	231	231	B (6)

Doppler sodar

The environmental parameters provided by this system are echo strength, horizontal wind speed, wind direction, standard deviation of wind speed, vertical wind speed, standard deviation of the horizontal wind speed (along and across wind), inversion and/or mixing height and stability class. From the obtained data, the atmospheric profile over the region regarding diurnal and nocturnal as well as seasonal variations of mixing height and stability class have been studied and analyzed. The increase in the wind speed with the height was observed during the entire observation period, which fits in the profile laws of ABL. The change in the atmosphere during the total solar eclipse on 24th October 1995 was studied and it was found that at no time during the solar eclipse, the atmosphere became stable (Bandyopadhyay et al., 2001). Similar observations were reported earlier by Singal et at. (1984) about the total solar eclipse on 16th February 1980. From the Doppler observation of the stability classes it has been seen that the behaviour of stability at different heights changes due to multiple factors. It has been classified that the lowest layer of the atmosphere is stable or unstable depending upon the value of the standard deviation of the vertical wind speed. The observed trend of stability class, however, shows that at the daytime in the lower heights the atmospheric stability is near 'unstable' while at the higher heights it is near to 'stable'. This phenomenon is also observed at night. Fig. 5 gives the continuous variation of mixing height over the Dhanbad region from to 4th to 6th December 1996. The variation of upper wind speed has been shown in Fig. 6. It has been observed that the mixing layer height in a typical winter day varies from fifty to five hundred meters.

Micro-meteorological parameters of the Dhanbad region were also measured by continuous meteorological station at CMRI, Dhanbad. A typical data sheet of various meteorological parameters measured on 30th January 1997 by Doppler radar as well as by continuous meteorological station at Dhanbad is presented in Table 4.

APPLICATION OP SODAR

Acoustic Sounding System, popularly known as sodar is a useful and inexpensive device for studying and analyzing the various meteorological parameters in the ABL (McAllister, 1968; Kumar et al.. 1986; Singal, 1990). This is an important tool for monitoring the dynamics of lower atmosphere over the antenna site. The transport and dispersion of pollutants in the atmosphere is governed largely by meteorological factors, many of which vary considerably in space and time (Best et al., 1986). Thus, to assess the likely impact of air quality of a proposed new industrial development, or to understand problems that may be occurring near an existing pollution source, it is often necessary to carry out an on-site continuous meteorological measurement.

Acoustic sounding is the most attractive and effective remote sensing technology to interrogate the atmosphere with good spatial and temporal resolution (George and Clifford, 1972; Singal, 1997). The system provides continuous information of:

i) Mixing height and stability classification of atmosphere for air pollution modeling (Singal, 1985; Singal, 1988; Singal 1989; Beyrich, 1995; Beyrich. 1996; Beyrich, 1997; Bandyopadhyay et al., 1997; Prasad et al., 1997; Chaulya et al., 2000; Chaulya et al., 2001).

Table 4. Typical data sheet ofmicro-moteorological parameters at Dhanbad

Time (HH:MM:SS)	Total Rainfall (mm)*	Wind Speed (km/h)*	Wind Direction from (Degree)*	Air Temperature. (° C)*	Relative Humidity (%)*	Barometric Pressure (mb)*	Mixing Height (m)#	Stability Class (Pasquill)#
01:00:00	0.00	0.40	306	14.56	15	985	95	4
02:00:00	0.00	1.71	278	14.14	16	985	97	4
03:00:00	0.00	0.64	245	12.49	14	984	86	5
04:00:00	0.00	0.40	169	11.97	19	983	86	5
05:00:00	0.00	0.40	120	11.10	24	983	93	5
06:00:00	0.00	0.40	181	10.91	29	984	126	5
07:00:00	0.00	0.40	303	11.54	18	984	77	5
08:00:00	0.00	0.40	327	13.29	16	985	166	5
09:00:00	0.00	0.73	156	16.84	38	987	110	5
10:00:00	0.00	2.92	222	19.40	63	988	434	3
11:00:00	0.00	2.84	163	21.35	70	988	823	2
12:00:00	0.00	2.86	181	22.64	75	987	686	3
13:00:00	0.00	3.32	179	23.65	81	986	564	3
14:00:00	0.00	3.96	177	24.54	88	985	513	2
15:00:00	1.02	3.90	210	25.35	94	984	455	1
16:00:00	0.00	1.78	188	25.25	90	983	650	3
17:00:00	0.00	0.40	201	24.48	76	983	209	5
18:00:00	0.00	1.41	227	21.62	63	982	131	5
19:00:00	0.00	0.40	230	19.15	58	982	203	5
20:00:00	0.00	0.40	235	17.81	53	982	465	4
21:00:00	0.00	1.48	262	16.55	48	982	220	3
22:00:00	0.00	1.52	191	16.02	35	982	203	4
23:00:00	0.00	1.39	309	14.92	20	982	130	3
24:00:00	0.00	0.39	297	14.56	13	982	128	5

ii) Thickness of ground based inversion, duration of existence, time and character of its development and decay (Singal et al., 1989; Melas, 1990; Beydch and Weill, 1993).

iii) Thickness and height of elevated inversion layers (Singal et al., 1986; Koracin and Berkowiez, 1988; Pahwa et al., 1990; Venkatesan et al., 1995).

iv) Wind profiles useful for weather prediction (Rao et al., 1981; Kumar et al., 1985: Peyrich and Gorsdorf, 1995; Seibert and Langer, 1996).

v) Turbulent properties of the medium (Weill et al., 1978; Singal and Gera, 1982; Singal et al., 1982; Wratt, 1987; Abbate et al., 1994).

vi) Air pollution meteorology (Hicks et al., 1977; Peter and Colls, 1981; Kumar et al., 1986; Rao et al., 1986; Etling, 1990; Gera and Singal, 1990).

The need to obtain input data for air pollution models and the necessity to use economic methods have resulted in growing effort to use remote sensing technique with acoustic waves. The results of air quality modelling are

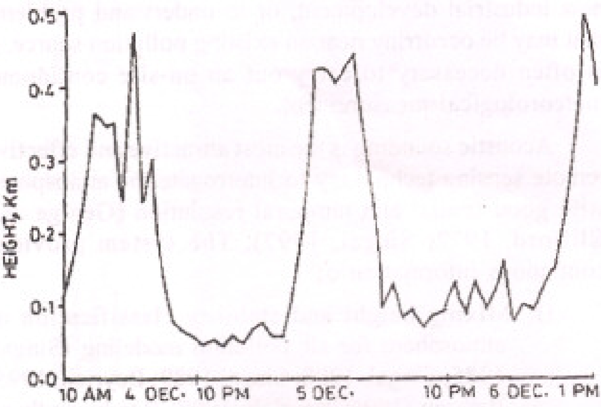

Fig. 5 : Variation of mixing height during 4th to 6th December 1996

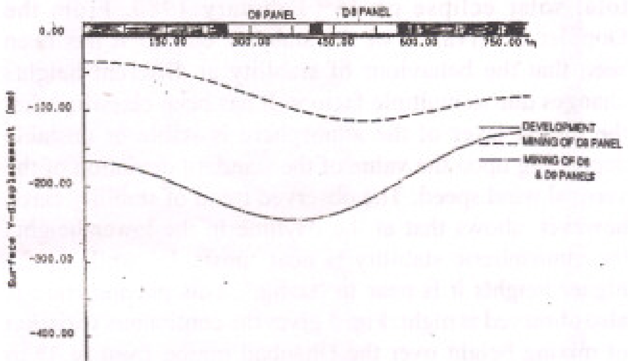

Fig. 6 : Series plot of wind speed at different heights

dependable to the input parameters to the models (Lal, 1996; Chaulya et al. 1999). There are four most important model inputs concerning meteorological data (Walczewski, 1990; Chaulya et al., 1998):

i) atmospheric stability.

ii) mixing layer height

iii) upper wind direction, and

iv) upper wind speed.

These data may be required in 2 forms: as the annual or seasonal statistics (for long rang impact calculations) and as the data files for extreme conditions (for calculations of impact in 'pollution episodes'). The Doppler sodar gives the abovementioned four types of data.

On the basis of air quality modeling and environment impact assessment, perspective plans and environmental management plan are prepared for location of industrial plants, roads, power plants, mining activity and other emission sources (Chauiya et al., 2000; Chaulya et al., 2001) Sodar study also helps in designing the chimney height and selection of operating time (i.e. time for releasing gaseous pollutants) based on the long-term data of mixing height, wind speed and direction, stability class and locations susceptible receptors (Bandyopadhyay et al., 1997).

CONCLUSIONS

The mono-static sodar can be used to identit' the turbulence sit,Mion in the atmosphere. However, such a system cannot give quantitative temperature profiles for use in dispersion models. For quantitative measurements of turbulence and wind, a Doppler sodar system is required. The knowledge of stability classification of the atmosphere can serve as a very useful tool for understanding the condition of dispersion of air pollutants (Singal. 1988). Atmospheric stability category and the dispersion of air pollutants are interdependent. Hence, sodar observations would be much helpful in environmental impact assessment. The deployment of a sodar in an area of proposed industrialization would provide statistical information on the probability of occurrence of different dispersion conditions and inversion height. Such information would provide guidelines on chimney height and intended gas cleansing standards as well as on the suitability of the scale or location of a project site. Finally, results of sodas observations are very useful for prediction of environmental pollution for any proposed project activities by air pollution modeling and thereby control of air pollution by development of green belt and other protection measures (Chaulya et al., 2001).

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